Journal of Transportation Engineering

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Technical Papers. Technical papers are full-length papers of value and interest to civil engineers. They must be original reviews of past practice, present information of current interest, or probe new fields of civil engineering activity. They should report results of thought-provoking studies that contribute to the planning, analysis, design, construction, management, or maintenance of civil engineering works. Technical papers should include a practical applications section whenever possible; theoretical manuscripts should indicate areas of additional research to implement technology transfer. Practical papers are strongly encouraged.

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Right Turns on Green and Pedestrian Level of Service: Statistical Assessment

Sarah M. L. Hubbard[1]; Darcy M. Bullock[2]; and Fred L. Mannering[3]

Abstract: Traditional pedestrian level of service measures at signalized intersections are based on pedestrian space and pedestrian delay. However, these measures may not adequately reflect the negative impact of right-turning traffic on pedestrians. This paper presents a statistical analysis using a binary logit model that provides new insights into the factors that affect the likelihood that a pedestrian is compromised (delayed, altered their travel path, or altered their travel speed) in response to traffic turning right (on green) during concurrent vehicle/pedestrian signal timing. The statistical analysis indicates that a number of factors affect the likelihood of a pedestrian being compromised including pedestrian direction of travel, right-turn traffic volume, number of pedestrians crossing, whether the pedestrian arrived late and began crossing after the end of the walk interval, and the crosswalk characteristics including location (downtown versus suburban) and one-way/two-way streets.

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Introduction

With the recent emphasis on mixed-use and walkable urban areas, the need to provide adequate pedestrian service has received increased attention in a number of policy and research reports [Federal Highway Administration (FHwA) 1994; Baxter 2004; Transportation Research Board (TRB) 2008]. However, measures of pedestrian level of service have been limited. Currently, the *Highway Capacity Manual* (HCM) (TRB 2000) considers only pedestrian delay and pedestrian space in assessing pedestrian level of service (LOS) at signalized intersections. For HCM pedestrian delay, only the duration of delay due to traffic signal control is considered—the negative impact of turning vehicles on pedestrian service is not. The HCM pedestrian space LOS methodology is based on crosswalk size, signal timing, and pedestrian and turning vehicle volumes. As a consequence, space per pedestrian and the associated LOS are reduced when more pedestrians are present. This measure also has a number of potential limitations. First, a crosswalk with a low to moderate pedestrian volume but a high volume of turning vehicles may have an adequate LOS, even though turning vehicles may cause delay and conflicts for pedestrians. Second, space is calculated based on the entire crosswalk and does not reflect whether the space available provides adequate gaps, or whether there is space available in the portion of the crosswalk traversed by turning vehicles. Third, pedestrian space LOS can be improved by increasing the width of the crosswalk even though increasing the crosswalk width is unlikely to reduce the negative impact of turning vehicles. Thus, neither of the existing HCM pedestrian LOS measures (delay or space) adequately captures the negative impact of turning vehicles on pedestrian service.

The operational framework for concurrent traffic/pedestrian service in the *Manual on Uniform Traffic Control Devices* (MUTCD) assumes that drivers yield to pedestrians, who legally have the right of way in the crosswalk during the pedestrian interval (FHwA 2003). However, field observations indicate that this assumption is not always valid (Hubbard et al. 2007; Van Houten et al. 2000; Zeeger and Stutts 2004; Zhang and Prevedouros 2003).

Driver failure to yield to pedestrians may present a safety problem as well as a mobility problem for pedestrians. Furthermore, the potential threat to pedestrians crossing at signalized intersections may be increasing over time due to increasingly aggressive urban drivers (Retting et al. 1999). In Washington, D.C., the incidence of pedestrian crashes due to driver failure to yield at a signalized intersection increased from 9% of all pedestrian crashes in 1976 to 25% in 1998 (Preusser et al. 2002). In Washington, this reflects an overall trend of increased pedestrian vulnerability at signalized intersections in urban areas, as the percentage of pedestrian crashes at signalized intersections increased from 26% of all pedestrian crashes in 1976 to 43% in 1998 (Preusser et al. 2002). Turning vehicle crashes included 45% of cases in which drivers were turning right, and 55% of cases in which drivers were turning left (Preusser et al. 2002). Due to limited information in crash reports, statistics are not available to indicate whether the drivers of right-turning vehicles were turning on red or green.

Pedestrians crossing with concurrent traffic/pedestrian service may have three potential conflicts with turning vehicles: right turns on a green (RTOG), permitted left turns on a green (LTOG), and right turns on red (RTOR). Permitted left turns and RTOR can be prohibited but the potential conflicts between pedestrians and right turns on green are more difficult to address. Enforcement of

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pedestrian right-of-way laws has proven difficult in many circumstances and, in some cases, enhanced enforcement may not be conducted without additional legislation providing stricter crosswalk codes (Harkey and Zegeer 2004).

To address the limitations of existing pedestrian LOS measures, Petritsch et al. (2005) developed a model of pedestrians' perceived LOS using ordinary least squares and ordered probit models with explanatory variables of pedestrian delay, vehicle volume and speed, and geometric characteristics of the crosswalk. The vehicle volumes included in the model are 15 min vehicle volumes for the RTOR and the permitted left-turn vehicle volume—both of which could potentially conflict with pedestrians. Vehicle volume for RTOG is included in the model only if there is an island separating the right-turn movement from the through movement. Furthermore, the pedestrians' perceived LOS is dominated by the number of lanes crossed. However, the pedestrians' perceived LOS is a noteworthy concept because it recognizes that pedestrian service is impacted by factors other than signal delay, and it identifies and quantifies factors that affect pedestrians' perception of service.

Over the years, many other studies have addressed pedestrian LOS and have found, to varying degrees, that vehicle/pedestrian conflicts play an important role in the determination of LOS with regard to pedestrian safety (Sarkar 1993; Quaye et al. 1993; Khisty 1994; Dixon 1996; Milazzo et al. 1998; Zhang and Prevedouros 2003; Steinman and Hines 2004; Petritsch et al. 2006; Akin and Sisiopiku 2007). However, safety-based service assessments often do not quantify the negative impact of turning vehicles on pedestrian delay. For example, conflict analysis may capture a vehicle swerving to avoid a pedestrian but it would not capture the delay and reduced service experienced by a pedestrian waiting on the curb while vehicles turn into the crosswalk during the walk interval, which presumably would have a significant impact on overall pedestrian LOS.

The intent of the current paper is to add to the growing body of literature on pedestrian level of service by focusing on the pedestrian-vehicle interaction caused by concurrent right-turning vehicles (right turning on green) at signalized intersections. To do this, we define pedestrian crossings as compromised if pedestrians are delayed or change their travel path or speed in response to right-turning traffic. This measure accounts for the more subtle elements of pedestrian LOS, such as pedestrian delay on the curb, pedestrian delay during crossing, pedestrian travel path changes, and pedestrian walking speed deviations—factors not generally considered by traditional pedestrian-LOS analyses.

Methodological Approach

Our analysis considers individual pedestrian crossings, which are classified as compromised (pedestrians delayed or observed to change their travel path or speed in response to right-turning traffic) or uncompromised (no delay or change in travel path/speed). This gives a binary outcome that can be coded as one if compromised and zero otherwise. In developing a statistical model of such discrete outcome data, a variety of modeling methodologies are available including logit, probit, and mixed logit models (Washington et al. 2003). A variety of modeling options were empirically tested (this will be discussed later in this paper) and the logit model provided the best overall results. For the structure of the standard multinomial logit formulation, McFadden (1981) has shown that if unobserved factors influencing the probability of alternate discrete outcomes (disturbances) are assumed to be generalized extreme value distributed, the standard multinomial logit model results

$$P_{\mathrm{in}} = \frac{\mathrm{EXP}[\boldsymbol{\beta}_i \mathbf{X}_{\mathrm{in}}]}{\Sigma_{\forall I} \mathrm{EXP}(\boldsymbol{\beta}_I \mathbf{X}_{\mathrm{In}})}$$

where P_{in}=probability that observation n results in discrete outcome I; $\mathbf{X}_{\mathrm{in}}$=vector of characteristics that determine the probability of discrete outcome i for observation n; $\boldsymbol{\beta}_i$=vector of estimable parameters; and I=set of available discrete outcomes. This model can be readily estimated using standard maximum likelihood methods (Washington et al. 2003). In this application, P_{in}=probability of a compromised pedestrian crossing for observation n; $\mathbf{X}_{\mathrm{in}}$=vector of observable pedestrian, intersection and vehicle flow characteristics for observation n; $\boldsymbol{\beta}_i$=vector of estimable parameters, which includes a coefficient for each pedestrian, intersection, and vehicle flow characteristic in $\mathbf{X}_{\mathrm{in}}$; and I=either 1 if the pedestrian crossing is compromised or 0 if the pedestrian crossing is not compromised by right-turning vehicles.

In the current study, there are only two possible outcomes (compromised and not compromised) so, without loss of generality, $\boldsymbol{\beta}_i \mathbf{X}_{\mathrm{in}}$ for the uncompromised outcome can be set to zero (Winston et al. 2006). From Eq. (1), this then gives the probability of pedestrian n being compromised (P_{cn}) as

$$P_{\mathrm{cn}} = \frac{1}{1 + \mathrm{EXP}(-\boldsymbol{\beta}_c \mathbf{X}_{\mathrm{cn}})}$$

To assess the effect of the vector of estimated parameters $\boldsymbol{\beta}_c$, elasticities are computed as

$$E_{x_{\mathrm{kcn}}}^{P_{\mathrm{cn}}} = \frac{\partial P_{\mathrm{cn}}}{\partial x_{\mathrm{kcn}}} \times \frac{x_{\mathrm{kcn}}}{P_{\mathrm{cn}}}$$

that gives [using Eqs. (2) and (3)]

$$E_{x_{\mathrm{kcn}}}^{P_{\mathrm{cn}}} = [1 - P_{\mathrm{cn}}]\beta_{\mathrm{kcn}} x_{\mathrm{kcn}}$$

where β_{kcn}=estimated parameter associated with the kth variable x_{kcn}. Elasticity values $E_{x_{\mathrm{kcn}}}^{P_{\mathrm{cn}}}$ can be roughly interpreted as the percent effect that a 1% change in x_{ki} has on the probability of pedestrian n's crossing being compromised P_{cn}. Although each pedestrian has an elasticity that depends on its value of x_{kcn} and the computed probability of its crossing being compromised (P_{cn}), it is customary to report the average elasticity over the sample population (we will report the average and the standard deviation of the elasticities over the pedestrian population).

As a final point, note that Eq. (4) is not applicable for indicator variables (those variables taking on values of 0 or 1). In these cases, pseudoelasticity can be calculated as (Washington et al. 2003)

$$E_{x_{\mathrm{ki}}}^{P_{\mathrm{cn}}} = \left[\frac{\mathrm{EXP}[\Delta(\boldsymbol{\beta}_c \mathbf{X}_{\mathrm{cn}})][1 + \mathrm{EXP}(\beta_{\mathrm{kcn}} x_{\mathrm{kcn}})]}{\mathrm{EXP}[\Delta(\boldsymbol{\beta}_c \mathbf{X}_{\mathrm{cn}})][\mathrm{EXP}(\beta_{\mathrm{kcn}} x_{\mathrm{kcn}})] + 1} - 1 \right] \times 100 \quad (5)$$

The pseudoelasticity of the variable with respect to compromised crossings is the percent change in the probability of a crossing being compromised when the variable is changed from zero to one. When computing the average pseudoelasticity for the pedestrian population, a pseudoelasticity of 75% means that when the value of the variable in the subset of pedestrians where x_k=0 is changed from 0 to 1, the probability of the crossing being compromised increased, on average, by 75%.

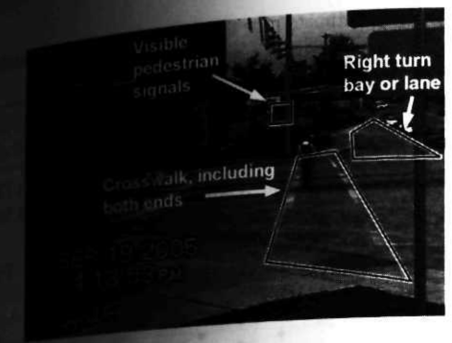

Fig. 1. Example video field of view

Empirical Setting

Pedestrian crossings were observed at 13 crosswalks at 10 intersections in four metropolitan areas (six crosswalks in Indianapolis, IN, one crosswalk in Cincinnati, OH, five crosswalks in West Lafayette, IN, and one crosswalk in Portland, OR). The data set included 849 pedestrian crossings at seven crosswalks in the central business district (CBD) and 455 pedestrian crossings at six non-CBD or suburban crosswalks. Approximately 76 h of video were recorded to provide the basis for determining compromised crossings. An example of the typical video field of view is shown in Fig. 1. The video field of view included the right-turn lane, the pedestrian signal indication, and the entire crosswalk.

Characteristics about pedestrians included the direction of pedestrian travel, pedestrian compliance, the number of pedestrians crossing together in a platoon, the number of pedestrians crossing during the pedestrian interval (traveling in both directions), and whether the pedestrian's crossing was determined to be compromised due to right-turning traffic. The direction of pedestrian travel (distinguished by near-side and far-side) was also determined as shown in Fig. 2. As shown in this figure, near-side pedestrians may be interrupted by right-turning traffic as soon as they step off the curb whereas far-side pedestrians may not be interrupted by right-turning vehicles until they are near the end of the crosswalk. Although not addressed by this study or reflected in this data set, pedestrians may be at risk for potential conflicts in a larger portion of the crosswalk at intersections where there are multiple exclusive right turning lanes.

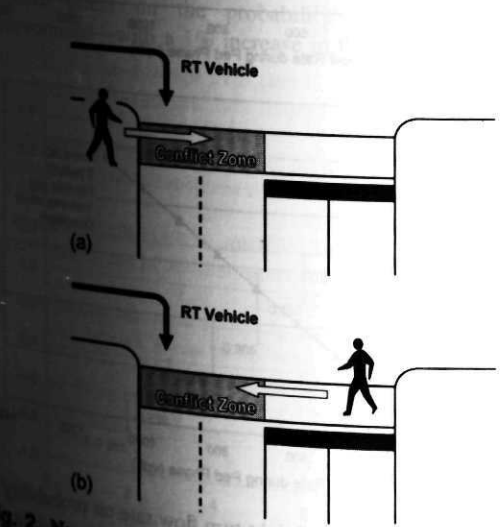

Fig. 2. Near-side and far-side pedestrian definitions: (a) near-side pedestrian (enters conflict zone at beginning of walk phase); (b) far-side pedestrian (enters conflict zone near end of walk phase)

Table 1. Sample Summary Statistics

Variable	Value
Percent of all pedestrian crossings compromised	13.8
Average right-turning vehicle flow during walk and clearance intervals in veh/h (standard deviation)	487 (283)
Percent near-side/far-side pedestrian[a] crossings	42/58
Average number of pedestrians in signal cycle (standard deviation)	3.18 (2.45)
Percent pedestrian crossings late	22
Percent pedestrian crossings in central business district	65
Percent pedestrian crossings on crosswalk traversing one-way street	42
Percent pedestrian crossings at Edwards and Erie, Cincinnati, Ohio	5
Percent pedestrian crossings from Indianapolis, Ind.	59
Percent pedestrian crossings at Powell and 82nd, Portland, Ore.	10
Percent pedestrian crossings from West Lafayette, Ind.	26

[a]See Fig. 2.

Table 1 presents summary statistics for the data collected for this study. The table shows that 13.8% of all pedestrian crossings were considered compromised (pedestrian delayed, altered travel path, or altered travel speed in response to right-turning traffic). The table also shows that the average right-turn flow rate during the pedestrian interval was 487 vehicles per h, which corresponds to an average vehicle headway of 7.4 sec per vehicle and an average right-turn volume of 3.6 vehicles during the pedestrian interval. The pedestrian interval includes the walk interval (average duration 9 sec) and the pedestrian clearance interval (average duration 18 sec).

There were more far-side pedestrian crossings (58% of the observations) than near side crossings (42% of the observations) in the data set. This may reflect directional imbalance associated with the times of day that the data were collected.

The average number of pedestrians crossing during a cycle was 3.18, and the data ranged from a single pedestrian to 17 pedestrians. Twenty-two percent of the pedestrian crossings were designated late, which indicated that the pedestrian arrived at the origin curb after the end of the walk interval, and entered the crosswalk during the pedestrian clearance phase. Three of the crosswalks had countdown pedestrian timers (all of these crosswalks were traversing one-way streets in downtown Indianapolis, IN); however, this factor was not statistically significant due to the high collinearity with the one-way street variable (discussed below).

Sixty-five percent of the crossings were observed at crosswalks in a CBD or shopping district, and 35% of the crossings were observed at non-CBD crosswalks. CBD crosswalks were located in Indianapolis, IN and in Cincinnati, OH. Non-CBD crosswalks were located in West Lafayette, IN and Portland, OR.

Forty-two percent of the pedestrian crossings were on crosswalks traversing a one-way street of four or five lanes; the remaining 58% of the pedestrian crossings were on crosswalks traversing two-way streets. All of the crosswalks traversing one-way streets were in downtown Indianapolis, and the one-way streets had four or five lanes of traffic. The two-way streets in the data set ranged from two to six lanes, with a conflict zone of one

Table 2. Model Estimation Results for the Probability of a Pedestrian Being Compromised

Variable	Parameter estimate	t-statistic
Constant	−5.458	−4.537
Natural log of right-turning vehicle flow during walk and clearance intervals (in veh/h) if near-side pedestrian,[a] 0 otherwise	0.760	4.002
Natural log of right-turning vehicle flow during walk and clearance intervals (in veh/h) if far-side pedestrian,[a] 0 otherwise	2.072	6.729
Far-side indicator (1 if far-side pedestrian,[a] 0 otherwise)	−8.688	−3.771
Total number of pedestrians in signal cycle	−0.228	−3.975
Late arrival indicator (1 if the pedestrian arrives at the intersection late and leaves the curb after the end of the walk interval, 0 otherwise)	0.497	2.537
Central business district indicator (1 if the intersection is in a central business district, 0 otherwise)	−1.068	−3.294
One-way street indicator (1 if pedestrian is crossing a one-way street, 0 otherwise)	0.631	1.930
Number of observations	1,304	
Log likelihood at zero	−903.86	
Log likelihood at convergence	−437.99	

[a]See Fig. 2.

Table 3. Elasticity Estimates for the Probability of a Pedestrian Being Compromised

Variable	Average elasticity (standard deviation)
Natural log of right-turning vehicle flow during walk and clearance intervals (in veh/h) if near-side pedestrian,[a] 0 otherwise	3.7% (0.3[illegible]%)
Natural log of right-turning vehicle flow during walk and clearance intervals (in veh/h) if far-side pedestrian,[a] 0 otherwise	See Fig. 5
Far-side indicator (1 if far-side pedestrian,[a] 0 otherwise)	See Fig. 5
Total number of pedestrians in signal cycle	−0.65% (0.56%)
Late arrival indicator (1 if the pedestrian arrives at the intersection late and leaves the curb after the end of the walk interval, 0 otherwise)	52.8% (9.6%)
Central business district indicator (1 if the intersection is in a central business district, 0 otherwise)	−60.0% (4.6%)
One-way street indicator (1 if pedestrian is crossing a one-way street, 0 otherwise)	69.6% (16.2%)

[a]See Fig. 2.

or two lanes of traffic (there were one or two receiving lanes for right-turn vehicles).

Estimation Results

Model estimation results are shown in Table 2 and corresponding variable elasticities are shown in Table 3. Graphs illustrating the probability of a compromised pedestrian under a variety of sample conditions are shown in Figs. 3 and 4. All estimated parameters are statistically significant and of plausible sign. The overall model fit is quite good with the log likelihood increasing from −903.86 when $\boldsymbol{\beta}_c=0$ to −437.99 when $\boldsymbol{\beta}_c$ is at its converged value. This results in a very reasonable ρ^2 of 0.515 (computed as one minus the log likelihood at convergence minus the log likelihood at zero) (Washington et al. 2003).

Examining specific estimation results, we find that higher right-turn vehicle volumes (entered as the natural log of right-turn vehicle volume) increases the probability of a near-side pedestrian being compromised, as expected. The elasticity of this variable is 3.7 (as shown in Table 3). This means that a 1% increase in the right-turning vehicle flow will increase the probability of a pedestrian-crossing compromise by 3.7%. This and all elasticity values presented are valid for small changes in variable, in this case the right-turn flow rate.

Higher right-turn vehicle volumes for far-side pedestrians (as with the near-side case) increases the probability of being compromised. However, far-side pedestrians have an inherently lower probability of being compromised (relative to near-side pedestrians) as indicated by the negative value of the far-side indicator variable. The net effect of these far-side variables in terms of elasticities is illustrated in Fig. 5. The average elasticity for varying flow rates is shown, as is the standard deviation of the elasticity, illustrated in Fig. 5 as an error bar. At low right-turn flow rates, corresponding to four or fewer vehicles during the pedestrian interval, the elasticity is negative, indicating that the net effect is less likely to be compromised by right-turning vehicles for far-side pedestrians. However, as the right-turn flow rate increases, the elasticity switches signs, becoming positive for five right-turning vehicles during the pedestrian interval—with a maximum value of 0.4 for a right-turn volume of 10 vehicles during the pedestrian interval (10 vehicles was the maximum value observed in the data set with an adequate number of observations). This value is still significantly less than the 3.7 elasticity for near-side pedestrians, underscoring the high sensitivity of near-side crossings relative to their far-side counterparts. These differences in the service for near-side and far-side pedestrians at different right-turn flow rates may be the result of a number of factors. For example, at low vehicle volumes, right-turn vehicles may turn at the beginning of the walk interval and clear the crosswalk without a conflict for far-side pedestrians—however, even a single right-turn vehicle may delay a near-side pedestrian.

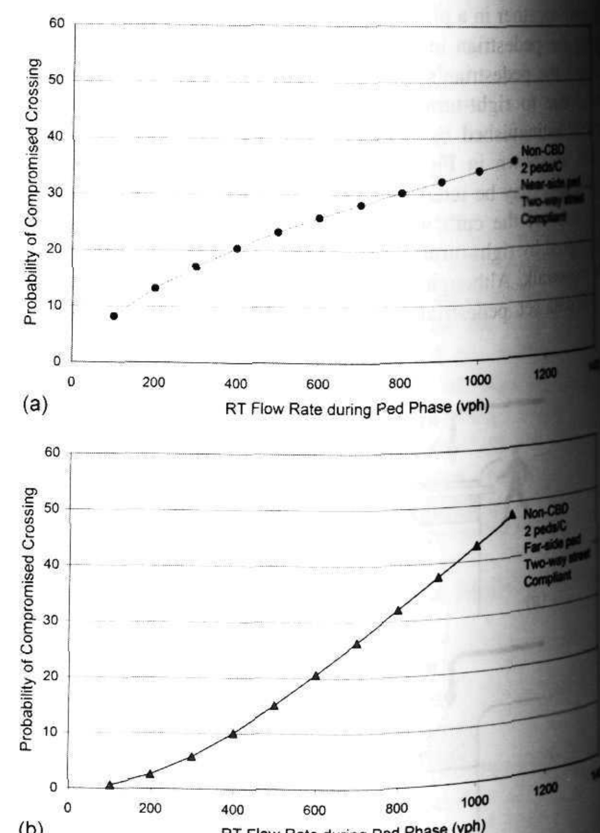

Fig. 3. Illustration of impact of right-turn flow rate on probability of compromise for near-side and far-side pedestrians: (a) probability of compromise for near-side pedestrians; (b) probability of compromise for far-side pedestrians

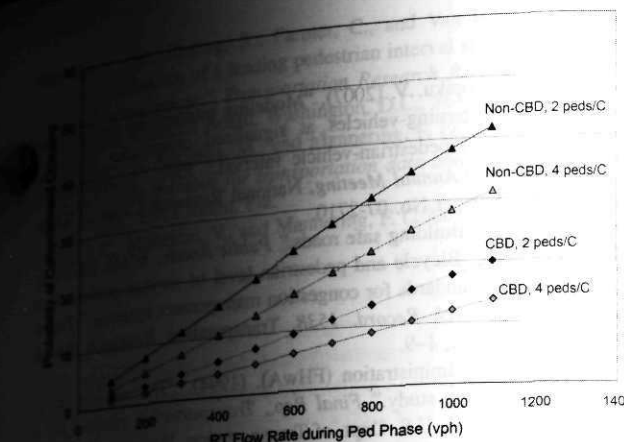

Fig. 4. Illustration of impact of CBD and number of pedestrians per cycle on probability of compromise (half-near and half-far side, compliant pedestrians crossing a two-way street)

Table 2 shows that an increasing number of pedestrians arriving during the signal cycle was found to have a significant negative effect on the probability of a pedestrian being compromised—with a 1% increase in the number of pedestrians arriving during the signal cycle decreasing the probability of a pedestrian-crossing compromise by 0.65% (see Table 3). This finding suggests that pedestrian LOS is improved when additional pedestrians are present (pedestrian volumes in our sample ranged from 1 to 17 pedestrians per cycle). This finding is also contrary to the traditional pedestrian space level of service measures in the *Highway Capacity Manual*, which indicate that additional pedestrians reduce the LOS.

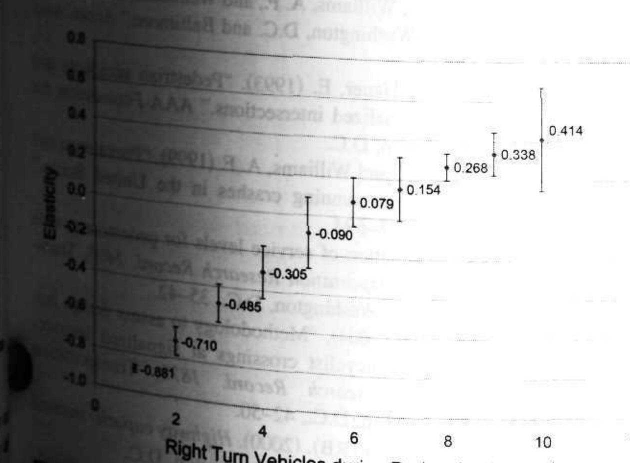

Fig. 5. Elasticity for combination of far-side variables (average and plus/minus one standard deviation)

Pedestrians that arrived late at the intersection and leave the curb after the end of the walk interval had a significantly higher probability of being compromised (see Table 2). Table 3 shows that pedestrians that arrived late were 52.8% more likely, on average, to be compromised than those that did not. Among other possibilities, it is speculated that late pedestrians may be more likely to be compromised because they do not have an opportunity to "stake their claim" to the crosswalk at the beginning of the walk interval.

As indicated in Table 3, pedestrians crossing intersections in a central business district (CBD) were 60% less likely to be compromised, on average, than those crossing non-CBD intersections. One possibility for this is that drivers in central business districts may be more likely to look for pedestrians and yield to pedestrians in the crosswalk.

Finally, crosswalks traversing one-way streets were found to increase the probability of being compromised by 69.6% on average (see Tables 2 and 3). When pedestrians cross a one-way street, the entire crosswalk is the conflict zone, because right turns can turn into any lane of the crosswalk. The conflict zone for the one-way streets in the database was four or five lanes of traffic, which translates into a much longer conflict zone than that for the two-way streets in the database—all of which had conflict zones spanning one or two lanes of traffic.

Model Estimation Tests

Because the central business district (CBD) was found to have a large effect on the probability of being compromised, statistical tests were conducted to determine if all of the model parameters varied between CBD and non-CBD locations (not just simply by a CBD indicator). To test for this, a likelihood ration test is applied and the appropriate statistic is

$$\chi^2 = -2[\mathrm{LL}(\beta_T) - \mathrm{LL}(\beta_{\mathrm{CBD}}) - \mathrm{LL}(\beta_{\mathrm{non\text{-}CBD}})] \qquad (6)$$

where $\mathrm{LL}(\beta_T)$=log likelihood at convergence of the model estimated with the data from both CBD and non-CBD pedestrian crossings; $\mathrm{LL}(\beta_{\mathrm{CBD}})$=log likelihood at convergence of the model using only CBD pedestrian crossings; and $\mathrm{LL}(\beta_{\mathrm{non\text{-}CBD}})$=log likelihood at convergence of the model using non-CBD pedestrian crossings. This statistic is χ^2 distributed with degrees of freedom equal to the summation of the number of estimated parameters in the CBD and non-CBD models minus the number of estimated parameters in the "total" data model. The calculated χ^2 statistic of 2.52 is much less than the critical χ^2 value of 7.78 for the 90% confidence level. Therefore, the hypothesis that CBD and non-CBD parameters are the same cannot be rejected and estimating a single model for all data is appropriate.

Because we have multiple pedestrian observations from each intersection, there is the possibility that the unobserved factors (disturbances) may be correlated for each intersection would violate the independence of disturbances assumption used to arrive at Eq. (1). To test for this possibility, we estimated a logit model

with random effects (Washington et al. 2003), but the random effects were statistically insignificant, thus, suggesting that the standard binary model was appropriate.

To test other discrete-outcome modeling approaches, a mixed (random parameters) logit model (Milton et al. 2008) and a binary probit model were also estimated using the data. When estimating the mixed logit model, no parameters were found to be random and, thus, a simple binary logit model with parameters fixed over the sample (as shown in Table 2) was appropriate. With regard to the binary probit model, the estimated signs and magnitudes of the variables were very similar to the logit-model results and we, thus, present only the binary logit model findings in this paper.

Summary and Conclusions

Our application of a binary logit model of pedestrian compromises shows that the probability of a pedestrian compromise increases with increasing right-turn vehicle flow rate, and is higher for crosswalks outside the CBD compared to crosswalks in the CBD for the same right-turn flow rate. The estimation results also show that: crossing from the far-side decreases the likelihood of a compromise at low right-turning vehicle volumes, additional pedestrians crossing during the cycle decreases the likelihood of a compromise, late pedestrian arrivals resulting in curb departures after the end of the walk interval increases the likelihood of a compromise, and crossing at a one-way street increases the likelihood of a compromise.

The findings show that pedestrian level of service is a complex concept that is determined by many factors. One important finding of this research is the implication that pedestrian service is enhanced by the presence of additional pedestrians rather than degraded by the presence of additional pedestrians. This finding contradicts currently used level of service methods that are based on pedestrian space.

This paper provides some initial insight into the rather complex effect that right turns on green have on pedestrian service. The findings underscore the importance of quantifying conflicting vehicle volumes during the pedestrian interval and considering this information when evaluating alternative signal timing strategies at signalized intersections. Current intersection level of service analysis quantifies the effect of pedestrians on right-turning vehicles, but does not consider the effect of right-turning vehicles on pedestrians, which is a potentially important oversight in determining overall intersection level of service.

The findings of this research regarding pedestrian direction of travel may also be relevant when considering the potential benefits of a leading pedestrian interval (LPI) to improve pedestrian service at a signalized intersection. An LPI provides a pedestrian head start at the beginning of the walk interval, and has been reported to improve pedestrian service (Van Houten et al. 2000). Critics of LPIs may contend that this strategy only helps near-side pedestrians. The findings of this research indicate that near-side pedestrians may be more likely to be compromised (especially at low right-turn flow rates) and, thus, a strategy that addresses the needs of near-side pedestrians may be a very effective one.

In terms of future work, it would be interesting to consider more expansive database with crosswalks reflecting a wide range of geographic locations, geometric conditions, pedestrian volumes, and vehicle volumes. It would also be interesting to expand the data and statistical evaluation to include other vehicle-turning possibilities such as permitted left turns and right turns on red, as well as right turns on green.

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